Towards a Knowledge Management Capability for ESG Accounting with the Help of Enterprise Modeling and Knowledge Graphs

Cristina-Claudia Osman[†], Ana-Maria Ghiran[†], and Robert Andrei Buchmann[*,†]

OMILAB@UBB-FSEGA, Faculty of Economics and Business Administration, Babeș-Bolyai University, Teodor Mihali Street, no. 58-60, Cluj-Napoca, 400591, Romania

Abstract

Managing ESG (environment-social-governance) policies becomes a critical need in small and medium enterprises, as pressure and requirements come from many stakeholders – legislation, banking, supply chain partners etc. The regional business environment where our research originates is absorbing this pressure by organizing frequent workshops with local business and IT clusters to find reusable solutions, to come up with ESG capabilities or to promote (software) products that may help with some aspect of ESG accounting. The data-centric and analytics approaches are prevalent in such workshops, offering quantitative reporting templates from data assumed to be available in legacy databases and spreadsheets - sometimes augmented with IoT solutions. However, ESG is not all about quantitative aggregations of data - as a complement to such efforts, an emerging requirement also calls for "how-to" guidance, mappings of granular data sources and their traceability to enterprise aspects – in short a knowledge management capability that can deal with where exactly ESG concerns manifest and propagate through enterprise layers. To meet this requirement, we advocate conceptual model-based analysis that puts emphasis on relationships, i.e. dependencies and traceability, rather than spreadsheets and data points. Our paper reports on initial Design Science steps to address the lack of ESG knowledge management capabilities by converging recent work on enterprise modeling and knowledge graphs, specifically by leveraging tools that integrate a knowledge graph treatment with BPMN and metamodel extensions that capture relationships relevant to ESG.

Keywords

ESG accounting, BPM, knowledge graphs, knowledge management capability

1. Introduction

ESG accounting aims to mitigate concerns regarding environmental impact, social responsibility, and corporate governance. It also raises requirements that small and medium enterprises (SMEs) must satisfy within rather urgent timeframes – such requirements are imposed by legislation, through financing institutions or business pressure along supply chains. SMEs must respond and design ways to self-evaluate governance performance and sustainability in relation to the environment, but support for this comes primarily as data-driven reporting tools rather than prescriptive methods.

During a series of workshops held in our regional business environment, we arrived at the motivating conclusion that ESG is not strictly a use case for data analytics, it is a systemic concern that must also be tackled by means of Information Systems analysis. The workshops involved, besides SMEs interested in building their ESG accounting capabilities, several other types of stakeholders: (a) software providers promoting ESG tools, (b) legal stakeholders and regulators warning that ESG is a matter of systems-of-systems, and (c) funding bodies exemplifying systemic constraints that emerge from ESG, including mechanisms of propagating those constraints.

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[*] Corresponding author.

[†] These authors contributed equally.

cristina.osman@econ.ubbcluj.ro (C. C. Osman); anamaria.ghiran@econ.ubbcluj.ro (A. M. Ghiran); robert.buchmann@econ.ubbcluj.ro (R. A. Buchmann)

0000-0002-9706-2915 (C. C. Osman); 0000-0001-7890-9386 (A. M. Ghiran); 0000-0002-7385-1610 (R. A. Buchmann)

This calls for organizations to ensure semantic traceability of ESG concerns, to become aware of how those concerns relate to various aspects of an enterprise and its existing processes. Traditional enterprise systems analysis and design successfully employed conceptual modeling methods, and enterprise knowledge graphs are a state-of-the-art approach for data integration and traceability. The hereby reported work aims to leverage both in order to build a novel ESG knowledge management capability where ESG concerns, with their associated knowledge objects, data objects and responsibilities, are mapped on enterprise models and exposed to a "Knowledge Graph treatment" for semantic navigation/traceability and rule-based reasoning.

For this paper, we currently focus on business process management capabilities as a foundation on which ESG knowledge management capabilities can be built, however we envision that this idea can extend to many aspects of enterprise architecture management (EAM) – we employ the umbrella term of „enterprise modeling" to reflect such generalization potential.

ESG policies and risks do not have only an ideological role, promoting sustainability and social responsibility, they are already impacting investment decisions [1]. There is a need for more effectively managing the ESG-associated risks and governance issues and this demands a pro-active look at how ESG is integrated inside the enterprise architecture, not only a reactive stance to external demands and impositions. Even when associated with non-financial reporting, ESG policies can lead to enhanced profitability [2]. The European Union specifically prioritized ESG during recent years. B Corp certification [3] is awarded by B Lab to companies meeting certain ESG criteria: governance, employees, environment, community, and customer relations. High ESG ratings and improved performance, especially in the social dimension, can improve firm value by reducing risks, therefore thousands of companies over the recent few years achieved the certification [4].

Moving to the conceptual modeling context, in Business Process Management (BPM) organizations typically map on granular process tasks, estimates of times, costs and various dependencies commonly used for simulations or process analytics reports. The initial idea of our work was to repurpose such annotation mechanisms to reflect ESG concerns. On tooling level, metamodeling becomes a critical capability to extend legacy BPMN tools towards so-called DSMLs (domain-specific modeling languages) that hybridize BPMN with ESG conceptualizations. Sustainability concerns already have led to the emergence Green BPM [5], placing particular emphasis on the environmental impact of business processes; GRC (governance, risk, compliance) is gradually incorporated in tools of traditional BPM suites and vendors [6], however not leveraging yet the emergence of enterprise knowledge graphs, thus missing an opportunity (highlighted by this work) of conceptual convergence between the business view on ESG and the technological view on enterprise data. Such a convergence was hinted at in recent works for other application domains – e.g. for supply chain management [7] or for work systems [8]. The convergence is made possible by a systemic perspective and the semantic traceability requirements raised by such a perspective and can be transferred to new methods of ESG-aware BPM or EAM as envisioned in this paper.

Current ESG methods and tools, to be surveyed in Section 2, care mostly about quantitative computation – i.e. data aggregation/analytics for various score sheets structured according to ESG pillars. However, if "knowledge is in relationships" knowledge management capabilities must start from devising means of capturing and maintaining the intricate semantic networks that connect ESG concerns to business operations or enterprise architectures. For our work the starting point is BPM as a practice and BPMN as tool support extended towards ESG relevance. By integrating BPMN modeling into ESG methodologies, followed by the conversion of diagrammatic visualizations into knowledge graphs, we enable process-centric analysis through an ESG lens. Knowledge graphs enable the navigation of dependencies and the use of traceability as constraints for data aggregations and retrieval, thus supporting more informed decisions to drive ESG strategies.

The remainder of the paper is structured as follows: Section 2 establishes the landscape of current methods for reporting ESG factors. Section 3 introduces the problem and the originating motivation. The research methodology that hybridizes Design Science with a metamodeling framework is presented in Section 4. Section 5 formulates and exemplifies the proposal of repurposing and

expanding the scope of Business Process Management towards a process-centric ESG knowledge-driven approach. The paper concludes with an outlook to future work.

2. Background on ESG tooling

The *Environmental* aspect of ESG assesses the company's impact on the natural ecosystem, such as reducing carbon emissions, efficiently using resources in production processes, pollution, waste management, or efforts to produce eco-friendly products or provide sustainable services. The *Social* factors refer to the company's relationships with customers, workforce, local community, and other stakeholders. *Corporate Governance* focuses on upholding transparency, accountability, and ethical practices in company management. There are several tools helping companies to incorporate sustainable goals into companies' activities. A problem identified by a team of researchers at MIT Sloan is that ESG assessment diverges substantially among the tools that evaluate the ESG impact [9]. We have looked at several such tools and associated methodologies.

2.1. Morningstar

Morningstar Sustainalytics [10] utilizes three building blocks in calculating the ESG Rating: corporate governance, material ESG issues and idiosyncratic issues. The main building block of the ESG Risk Ratings is represented by Sustainalytics' set of material ESG issues, supported by 300 ESG indicators. It combines more than 300 criteria such as ESG risk, Management, Exposure, etc., drawing upon 10 international standards and norms like the Global Reporting Initiative [11], Sustainability Accounting Standards Board, or World Economic Forum [12]. Moreover, they categorize the companies according to 3 levels: Global 50 Top Rated, Industry Top Rated and Regional Top Rated. If a company is included in one of the categories mentioned before, the badge can be used in company's reports, on their websites, email signatures, social media channels etc. 2024 ESG Top-Rated Badges report shows the list of the companies and their qualificative [13], this top including 14000 companies operating globally across 14 industries.

2.2. Bloomberg

Bloomberg [14] offers a range of proprietary scores that enable investors to evaluate company or government disclosure and performance across diverse ESG aspects (e.g. sustainable products, climate exposure, ethics & compliance, board composition etc.). Bloomberg has defined several indexes to evaluate companies' sustainability, for example Bloomberg Gender-Equality Index (GEI). The report of Bloomberg Gender-Equality Index of 2023 includes 484 companies from 54 industries [15].

2.3. MSCI (Morgen Stanley Capital International)

MSCI ESG rating calculates a company's management or financially relevant ESG risks and opportunities [16]. It uses the 3 pillars of ESG divided into 10 themes and 33 ESG key issues [17]. Based on the final score, it provides 3 categories of results: leader, average and laggard.

2.4. Asset4 Framework

Asset4 Framework [18] was developed by Refinitiv, a London Stock Exchange Group (LSEG), a former division of Thomson Reuters. In 2019, LSEG acquired Refinitiv. Their tool's evaluation (Refinitiv) focuses on specific subcategories, including Emissions, Resource Usage, Innovation, Human Rights, Portfolio Product Responsibility, Human Resources, Community Management, Shareholders, and CSR Strategy. Unlike Morningstar Sustainalytics, Refinitiv collects companies' public data from their sustainability reports. LSEG measures 2 ESG relates scores: a*) ESG score* (assesses the company's ESG performance using publicly available and verifiable reported data) and b) *ESGC score* (integrates the ESG score with ESG controversies to offer a deep assessment of the

company's sustainability impact and behavior across time) [18]. The assessment comprises more than 630 ESG measures. Each indicator has a specific weight used in the final calculation, depending on the industry (e.g. the methodology from December 2023 provides the following data: for Hotels & Entertainment Services, the innovation measure weights 2%, while Healthcare Equipment & Supplies has 6% - these percentages are based on a sample ESG data, and they can vary). At the end, each company is classified in a category from A to D (ESG Leaders to ESG Laggards – like MSCI classification [17]).

2.5. GRESB

GRESB (Global Real Estate Sustainability Benchmark) [19] is an independent organization that offers verified ESG performance data and comparative benchmarks to investors and managers, focusing on real estate and infrastructure sectors. The GRESB Estimation Model (GEM) provides accurate estimates of missing data regarding energy consumption and greenhouse gas (GHG) emissions for members participating in the Real Estate Assessment offered by GRESB [20]. This model is based on a global database containing approximately 170,000 individual assets from various real estate markets.

2.6. OpenESEA

OpenESEA [21] is a modeling approach that can be used by organizations to assess their ethical, social, and environmental aspects. The primary benefit of the tool lies in its integration of diverse methods, including the B Impact Assessment, Common Good Balance Sheet, GRI Standards [11], Sustainable Development Goals Compass [22], UN Global Compact [23], and others. Organizations have the flexibility to incorporate the approaches of their choice. A series of direct and indirect indicators are extracted from the methods analyzed - e.g. total water used and lowest wage belonging to B Impact Assessment.

2.7. Research objective relative to the existing ESG tools

The existing ESG impact tools focus on aggregating indicators like reducing carbon emissions, optimal use of resources in the product process, optimal working conditions, workplace equality of opportunities etc. The research reported in this paper aims to complement current quantitative practices with an approach that enables the conceptualization of ESG policies and risks in terms of traceability of influences on various elements of enterprise architecture, including business processes, decision-making factors, properties/components of products and services. The widely adopted standards such as BPMN, DMN, ArchiMate, etc., do not inherently support through first class constructs the ESG perspective and this work aims to bridge the gap by leveraging our experience with metamodeling frameworks and their interplay with knowledge graphs.

3. Problem identification and motivating requirements

The originating circumstance of this work was a series of workshops organized by local industry clusters in our region (Cluj area, Romania) – typically IT-focused clusters promoting software products for ESG concerns, funding and regulatory bodies explaining business restrictions arising from ESG alignment and SMEs interested in this alignment and how their general management practices must change. While ESG requirements are still confusing for some companies, SMEs hope to „tick boxes" by acquiring some software products but most of them are aware this is insufficient, recognizing that ESG is a larger systemic paradigm that requires internal capabilities baked into the enterprise architecture (EA). Regardless of the advertised tooling, all workshops have lead to discussions on knowledge management concerns, on „how to manage" rather than how to write a report imposed by the regulations.

We've looked into knowledge management capability frameworks to try to compare their coverage with the awareness we observed during those workshops. APQC established a tool for assessing knowledge management capabilities [24], which proposes a taxonomy of capabilities consisting of 4 classes depending on the knowledge management practices and knowledge objects being explicitly managed:

- **Strategy:** pertaining to objectives, business case and budgeting;
- **People:** pertaining to resources, governance, change management and communications;
- **Process:** pertaining to knowledge flows, knowledge management methods and associated measurements;
- **Content & IT:** pertaining to content management and information technology.

The ESG solutions discussed in the SME workshops were missing most of these – in most cases we were able to only identify instances of: *objectives concerns* - what ESG aspects should be reported, for what purpose; *IT concerns* - from what IT systems some ESG-relevant data can be obtained; *communications concerns* - who needs to communicate which report to a certain ESG stakeholder (mostly to external ones such as authorities, lacking any preoccupation with internal knowledge flows and traceability). In isolated cases there have been also mentions of: *budgeting* (how a dedicated budget should be managed for ESG); *content management* (e.g. having a free structure wiki on how to build certain ESG reports); *governance* (e.g. having a recurring standard operating procedure for building reports and communicating them in due time).

Even for the recognized aspects, the general state of practice showed a general lack (a) of *relational connectivity* (and therefore of traceability) of ESG concerns and (b) of *agile granularity*, to be able to shift the level of aggregation for data by mapping it to diverse enterprise architecture elements. This manifests in a general inability to answer diverse competency questions regarding ESG – all data retrieval being inspired by the traditional accounting practices, with fixed procedures designed to feed a fixed report template, although ESG continuously evolves in both granularity and ontological models.

(a) The first point (lack of connectivity) requires a certain level of semantic interoperability - ensuring shared understanding within the organization of the involved concepts and how they map to the business objects and business operations. The workshops showcased a variety of off-the-shelf IT products offered for any application domain and imposing their own conceptualization, assuming manual input of data of unknown provenance and improvised granularity. The most advanced tools also involved IoT data retrieval (e.g. solar panels to improve sustainability of certain processes), but all tools were clearly designed starting from a rigid data model expecting direct data input, rather than an evolving ESG data fabric;

(b) The second point (lack of agility in granularity) refers to a need to ensure that ESG-relevant content can be mapped and drilled-down to EA elements - e.g. process tasks/events drilled down into subprocesses (in BPMN sense), application components, technology components, locations (in Archimate sense) drilled down to subcomponents/sublocations etc. This can extend the existing reporting practices on the same level of granularity as the already in-place BPM/EAM culture. On the other hand, at least for SMEs involved in the mentioned workshops, such a legacy culture was mostly absent; EAM was never mentioned, while BPM made its way to some extent in the context of the recent popularity surge of Robotic Process Automation, leading to the creation of various „process maps" as basis for RPA projects documentation.

These insights from the regional business context inspired the initiation of a Design Science project that leverages our experience as an OMILAB Node[2] with enterprise modeling, particularly with business process modeling and knowledge graphs, to come up with traceability mechanisms based on BPMN that compensate the two gap points indicated above. This can lead to a (BPMN-

[2] https://econ.ubbcluj.ro/omilab/

centric for now, to be extended to a full-fledged DSML) knowledge management capability for ESG accounting that leverages three key ingredients:

- procedural knowledge assumed to exist in a company;
- metamodeling to extend the process description vocabulary in order to incorporate ESG-relevant data attributes;
- knowledge graphs to maintain the contextual linking of all these information and to enable on-demand data retrieval - according to semantics of the BPMN-ESG hybridization and the granularity of drilled-down procedural knowledge (different levels of subprocesses, filtered by various criteria).

4. The DSR-AMME treatment development framework

The key challenges of absorbing ESG are not limited to ensuring a new business interface (i.e. transparency and reporting of ESG-relevant data). They also entail modifications in business processes (e.g. new tasks, new documents, new communication), entirely new processes (e.g. waste handling, circular processes), new properties attached to enterprise architecture elements (e.g. gender quotas per department), entirely new architecture components (e.g. ESG-oriented software products hooked in the IT architecture, solar panels as technological components). As we're now focusing only on BPMN, not all these are currently addressed in our work, but it is obvious that employing enterprise modeling for knowledge externalization – a new interpretation on Nonaka's knowledge conversion spiral [25] – requires such aspects to become first-class modeling constructs in the modeling grammar; therefore, a metamodeling framework is also required to build this capability.

Such a capability qualifies as a *Design Science Research (DSR) treatment* that needs to evolve iteratively as the scope, domain-specificity and granularity requirements for ESG evolve rather fast. Consequently, our work needs to follow a hybrid framework where the DSR iterative process, i.e. Peffer's process [26], incorporates in the *Design & Development* phase a "method engineering" framework that also entails the iterative deployment of DSMLs to make the proposed treatment operational.

As it is customary in the OMILAB community of practice when working on language customizations, we opt to apply AMME (Agile Modeling Method Engineering) [27] and to customize the existing BPMN implementation offered in the open tool BEE-UP [28], a typical approach employed in the past for domain-specific BPMN extensions [29]. BEE-UP is built on the ADOxx metamodeling platform and benefits from an ability to generate RDF graphs from the graph structure underlying any diagram - according to patterns introduced in [30] and recently made available as a built-in BEE-UP option. This enables a particular flavor of model-driven engineering that we labelled in the past as *model-aware engineering* [31] – i.e. the repository of models becoming a knowledge base to be probed by semantic queries and reasoning mechanisms, instead of being a graphical base of code patterns to be subjected to transformations based on a fixed schema.

Figure 1 suggests this hybridization of DSR and AMME leading to a reusable treatment development process for research work where the design proposition is captured in a DSML and made operational in a graphical modeling tool, with ADOxx suggested here as a low-code platform to achieve that operationalization. The resulting knowledge graphs will naturally preserve all customizations brought to the language, as metamodel constructs and annotation attributes are turned by the metamodel-aware converter into RDF classes and data properties, respectively.

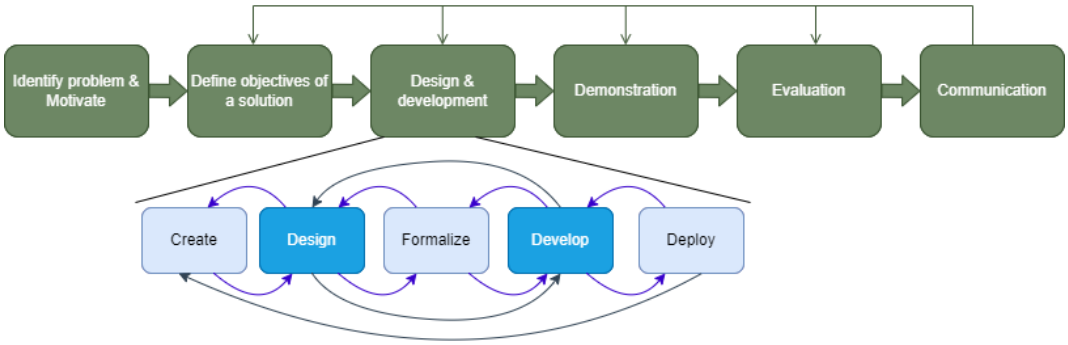

Figure 1: Hybrid DSR and AMME for modeling methods as DSR treatments

For the first DSR phase, we analyzed existing tools that are used for evaluating the ESG impact of organizations, as shown in Section 2. In recent years, efforts have been made globally (such as GRI Standards, B Corp certification, World Economic Forum, etc.) as well as at the European level (the Paris Agreement, Directive 2014/95/EU, EU Directive 2464, etc.) to standardize ESG policies by requiring the preparation of non-financial reports on companies' sustainability. EU member states transpose the European directive to their own legislation which means there can be significant variations due to national priorities and different foci on what is the relevant granularity level. Even if standards are available, legislation does not clearly impose a particular standard and different scores may be obtained depending on the domain-specific properties considered relevant in different sectors and even instance organizations. Agility at metamodel level and *streamlined externalization based on agile metamodel customizations* thus become a key requirement, in contrast to the traditional perception that diagrammatic modeling should comply to a fixed grammar – that criteria is relevant for the *model-driven* engineering use cases relying on model transformations, but it becomes irrelevant in the *model-aware* paradigm where arbitrary semantic enrichment must be captured as needed and as available (and immediately exposed to semantic navigation) [31].

The second stage of DSR asks for the definition of the objectives. The main objective is represented by the development of a model-based knowledge management capability for ESG accounting, operationalized in a visual modeling tool. Therefore, we looked at instances of ESG policies to identify properties and relations that can be "docked" to BPMN constructs.

The *Design and Development* stage, as shown in Fig. 1, was delegated to the AMME framework which has its own process for identifying modeling competence requirements and developing the tool to satisfy those requirements.

Returning to the main DSR cycle, *Demonstration* involves testing the feasibility of the treatment for selected cases that we identified in consulted SMEs, to be showcased in Section 5.

The *Evaluation* of the modeling method is for now limited to competence evaluation relative to requirements. Most evaluation criteria for tools developed on the ADOxx metamodeling platform inherit technical qualities (and limitations) from ADOxx – look and feel, performance, interoperability. We plan however to return to more comprehensive evaluations in terms of model comprehension and other criteria of the SEQUAL quality framework [32].

5. Proposal of BPMN-ESG-Knowledge Graph hybridization

The tools surveyed in Section 2, as well as tools advertised during the SME workshops that motivated this work, are fundamentally data-driven, assuming data availability (or suggesting potential provenance) and applying various taxonomies for report structuring. By applying the lens of knowledge management, we identify emerging requirements for traceability, agile granularity and mappings to enterprise architecture elements, even in cases when an enterprise architecture management practice is absent. EAM (re)surfaces as a frame for ESG concerns; even when EAM is not explicitly mentioned, elements of EA are mentioned as categories and traceability criteria for ESG attributes. Out of the EA layers we currently focus on business process descriptions based on

BPMN with some extensions to support certain semantic query and reasoning competencies over knowledge graphs obtained from those process descriptions, with the help of the diagram-to-RDF converters available in both BEE-UP (our BPMN tool of choice) [28] and the ADOxx metamodeling platform (for extending the modeling competence / metamodels of BEE-UP) [30]. Therefore, we currently advocate for an ESG knowledge management capability to be grafted over a pre-existing Business Process Management practice. BPM is also interested in quantitative indicators and their simulation, but compared to state-of-the-art ESG tools has a fundamental interest in the conceptual workflow structure and process decompositions. This ensures a granular semantic network to which knowledge objects and knowing subjects can be connected on a diagrammatic level and exposed to the knowledge graph treatment.

We hereby showcase two techniques for this treatment, exemplified by SPARQL queries that illustrate case-based competency evaluations: (a) **Attribute-centric** – this is the simpler approach derived from the traditional data-focused approach where ESG attributes (e.g. carbon footprint, employee genders) are annotated to model elements, additional to the traditional BPMN attributes typically used in simulations, and then collected by recursive queries over tasks or processes of desired granularity; (b) **Relationship-centric** – this implies the linking, via ADOxx hyperlinks, of BPMN elements to knowledge objects and knowing subjects or responsibilities from complementary custom diagrams that maintain an inventory of knowledge objects and an organizational chart making explicit ESG roles and even instance employees.

For the first approach we showcase an example in Figure 2 describing a hiring process with one level of embedded subprocesses and granular linking to performing employees. The recruitment process consists of several subprocesses like the *Preparing process, Sourcing process, Screening process* etc. Some of the subprocesses are also decomposed (*Preparing process, Sourcing process* and *Onboarding process*). The process participants can be modeled by default in BEE-UP by using the Working Environment Model – as instance employees, as roles, as departments and visual connections between them. Any of the work environment elements can be linked to BPMN tasks – something initially used for simulation purposes and later added to BEE-UP to maintain RACI links (Responsible-Accountable-Consulted-Informed). In this example the Marketing Department needs a new employee (e.g. a Marketing Officer). Besides the Marketing Department, HR Department and IT Department are also involved in the recruitment process (for example the manager of the Marketing Department must send the welcome pack to the new hired employee and the IT Department must prepare the technical details – on the *Onboarding* subprocess).

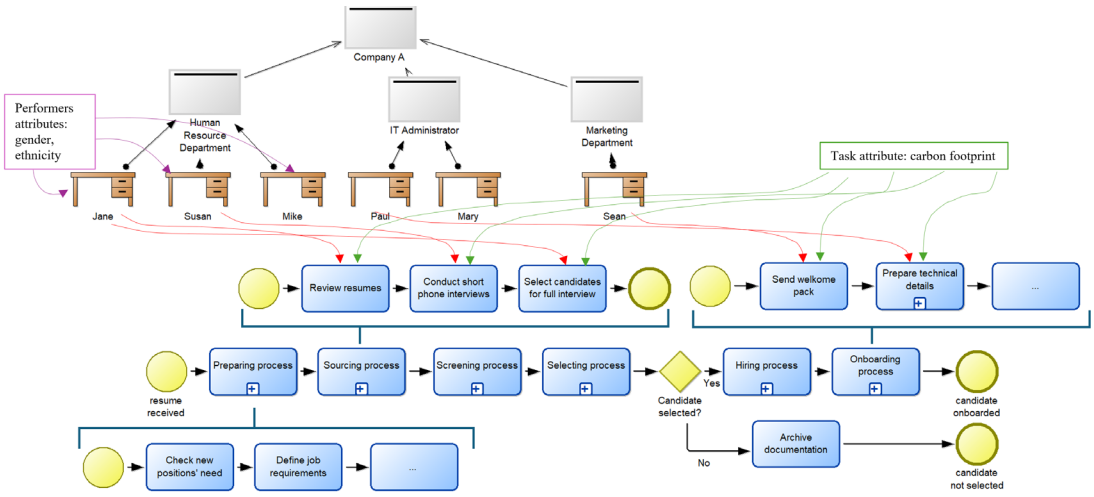

Figure 2: ESG attribute-centric BPMN models with work environment mappings

Attribute centricity means that ESG-relevant attributes are collected and annotated for various model elements: employees can get annotated with attributes such as gender, ethnicity; BPMN tasks get annotated with values for carbon footprint, energy consumption, waste generation.

Documenting such data around processes will help with, for instance, calculating the carbon footprint or energy consumption for each subprocess/process; measuring the waste generation (e.g. paperwork consuming physical paper); showing the gender quotas involved in each process/subprocess/task type.

The query examples below calculate for each department and for all manual tasks in each process (as named graphs):

```
SELECT ?dept (COUNT(?emp) AS ?femaleCount)
{
?emp a :Performer; :belongsTo ?dept; :gender “female”.
?dept a :OrganizationUnit.
}
GROUP BY ?dept

SELECT ?process (COUNT(?emp) AS ?femaleCount)
{
GRAPH ?process {?t a :BPMNTask; :taskType “Manual”; :responsible ?emp}
?emp a :Performer; :gender “female”
}
GROUP BY ?process
```

For the *Relationship-centric* approach, we remain in the hiring scenario with the example in Figure 3 where a new subtype of BPMN data object is introduced - visually marked with “esg” and distinguishable at metamodeling level to facilitate semantic queries. The figure shows (a) on the left side, fragments of the recruitment process producing or consuming such ESG data objects; (b) on the right side, an inventory of knowledge objects that produce the ESG data objects involved in certain BPMN tasks (e.g. requirements or onboarding packages for the open positions), or are informed by such objects (e.g. an ESG report that needs to be built by collecting data from certain tasks); (c) on top, again the work environment (organization chart) whose elements can include ESG specific roles and can be linked to knowledge objects.

There two pathways visible to achieve RDF linking: linking constrained by the metamodel (visual hyperlinks available to all diagrammatic elements of a certain type, for example links from knowledge objects to roles in the organization chart) and linking unconstrained by the metamodel (live URI and RDF triples that may adopt any description vocabulary, for instance Schema.org). A fragment from the knowledge graph thus derived, based on transformation patterns discussed in [30], is shown in Fig. 4 with some examples of semantic queries enabled by the resulting structure listed in the following:

Rule example: Generate a direct dependency relationship between two knowledge objects that are involved in the same BPMN task, one informed by ESG data objects generated by the task and the other exposing data objects needed in the task:

```
CONSTRUCT {?x :dependsOn ?y} WHERE
{
?x a :ESGKnowledgeObject; :informedByDataObject ?dx.
?y a :ESGKnowledgeObject; :exposedDataObject ?dy.
?dy a :ESGDataObject; :hasDataAssociation/:hasDataAssociation ?dx.
?dx a :ESGDataObject.
}
```

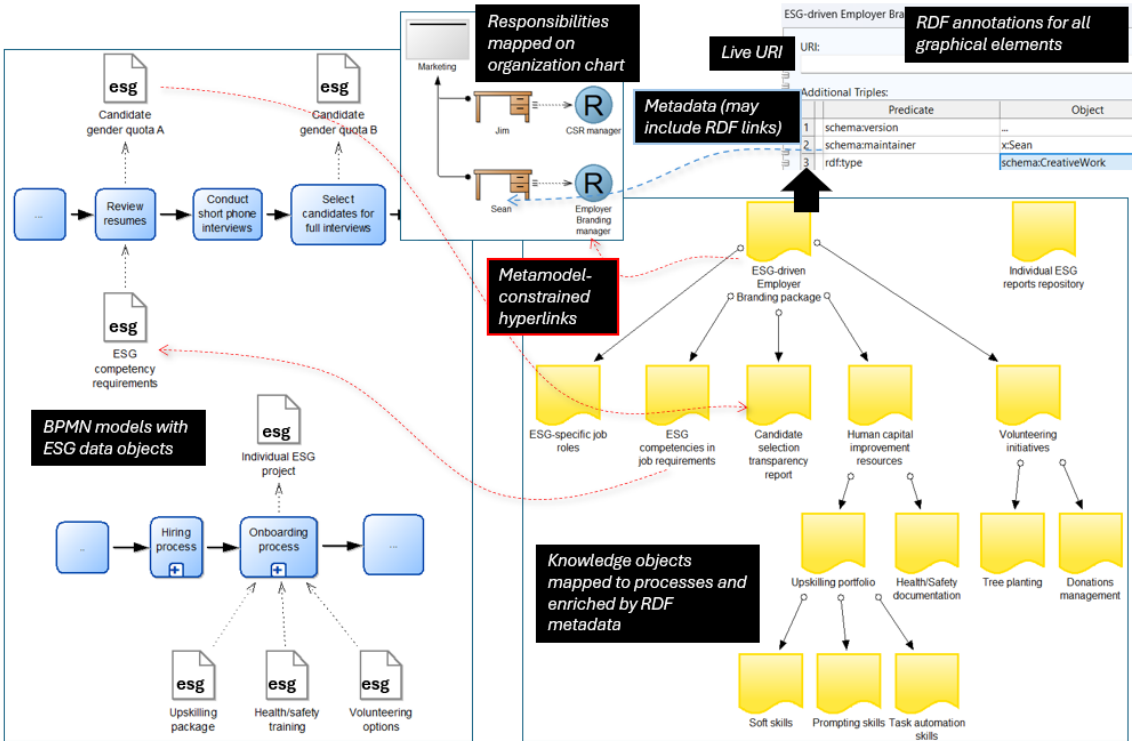

Figure 3: ESG KM-oriented extensions to BPMN

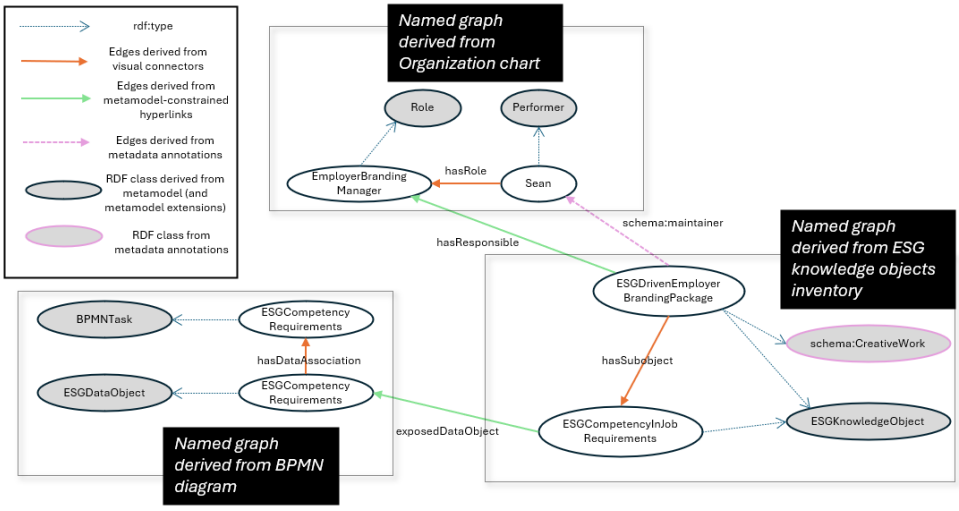

Figure 4: Knowledge graph fragments derived from the example in Fig. 3

Traceability example: Select all ESG data objects produced during a specific process, as well as the ESG knowledge objects that will be informed by those:

```
SELECT ?x ?y WHERE
{
GRAPH :SourcingProcess {?t a :BPMNTask; :hasDataAssociation ?x.
                        ?x a :ESGDataObject; ^:informedByDataObject ?y}
}
```

Aggregation example: Collect all processes whose tasks have a data input from objects derived from all knowledge objects subordinated to the Employer Branding Package.

```
SELECT DISTINCT ?process WHERE
{
```

```
GRAPH :MyKnowledgeObjects
                    {:ESGDrivenEmployerBrandingPackage :hasSubobject+ ?subObj.
                    ?subObj :exposedDataObject ?dObj}
GRAPH ?process {?t a :BPMNTask. ?dObj :hasDataAssociation ?t; a :ESGDataObject}
}
```

6. Conclusions

Integrating ESG factors at business process level enables organizations to systematically analyze and trace the sustainability design through a knowledge management lens. By measuring and monitoring ESG factors at the task level, organizations can identify areas for improvement, ensure repeatability of ESG processes, or reuse of knowledge assets.

SMEs face major challenges with aligning their business operations with the ESG criteria, but support typically comes in the form of software products to aggregate data assumed to be already available. ESG assessment should be also facilitated internally, through prescriptive methods allowing organizations to maintain, design and manage the knowledge pertaining to their ESG policies and risks. Coming from the side of BPM, traditional business process diagrams have a major use case in annotating times, costs, etc. for process-centric reporting purposes. This can be naturally extended to incorporate the ESG perspective - not only for documentation purposes, but also in a machine-readable manner with the help of knowledge graphs that can expose the BPMN-ESG hybridization. This motivated the objective of our research - to build a method potentially leading to a knowledge management capability for ESG policies traceable to enterprise architecture elements; for now, the work was limited to a few BPMN extensions. By applying the "Knowledge Graphs treatment" to those extensions, it becomes possible to use graph-based techniques (e.g. semantic queries) for analyzing, and reasoning about business processes, enabling richer insights and supporting various tasks such as process optimization, and decision support (e.g. identify process tasks with significant carbon emissions or excessive paper consumption).

Future DSR iterations will focus on developing a full-fledged DSML that reflects the ESG specificity more deeply – dedicated task types, event types, document types, circular processes, taxonomies of knowledge management assets maintained along business operations. In longer term, we are also considering the use of Large Language Models as a query mechanism over the resulting knowledge graphs, through hybrid AI configurations such as GraphRAG acting as a knowledge retrieval mechanism to reduce the reliance on SPARQL and associated technical skills.

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